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ABSTRACT

An approach which is designed to help students better understand the utility of models in understanding and doing physics, specifically in a course in light and color, is described in this paper. Explanations are given and illustrations are provided of an analogue model of waves which assist in the creation of an abstract model to deduce Snell's Law. A series of viewgraphs and overlays are included. The advantages of this approach are that (1) students see the evolution from a demonstration of the phenomena through the typology to the abstract model which can be proposed as a paradigm; (2) the proposed paradigm can be tested by its power in deducing previously obtained empirical results; and (3) students are enabled to acquire a better understanding of the use of models in doing physics. (ML)

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FROM ICONS TO PARADIGMS IN LIGHT AND COLOR

J. B. Newman

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AAPT/APS Joint Winter Meeting. Atlanta, Georgia. 30 January 1986

Paper JG6. From Icons to Paradigms in Light and Color

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Experience in teaching a course in Light and Color has shown that many students need help in understanding the normal use of models. By normal use is meant the practise of designating a drawing, demonstration or equation as a "model" and leaving it to the student to grasp the intended relationships. Non-science students do not find this practise to be helpful in asking questions, explaining the phenomenon, or solving simple problems. Efforts to improve this situation led me, through conversations with other teaching colleagues, to the typology of Haggett [Peter Haggett, Geography, a Modern Synthesis, 3rd edition (Harper and Row, New York, 1983, p. 18]. Haggett's typology is shown on the first viewgraph, (VG 1), My students have been helped in seeing the evolution of physical models through the adaptation of this typology to the subject matter of light and color. I shall show how I have adapted it to physics teaching by starting with an (icon)ic model of a laser beam bent at an air-water interface and ending with the wave model (as a paradigm) to deduce Snell's Law. The typology and evolution of the models are shown through a series of viewgraphs. A drawing of a laser beam incident on an air-water interface is shown in the next viewgraph, (VG 2). This drawing was described by my graphics colleague as "user-friendly." A similar drawing by a physics teacher might be more like the next one, (VG 3). Either serves as an iconic model; most of the details are given with a scale or dimensional change. Figure 3, (VG 4), shows an analogue model where the light rays, interface and normal lines show the essential features, in analogy to the "user-friendly" drawing. (The equations were covered by a three-by-five

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card.) The creation of an abstract model comes by adding quantifiable concepts to the analogue model. (The card was now removed.) At this juncture, it is emphasized to the students that Snell's Law was initially established by empirical methods; but the implicit ray model fails the criteria for a paradigm because of its (demonstrated) inadequacies in the explanation of diffraction and interference. In the course material, another model must be proposed and tested. Water waves are presented as an analogue model by demonstrating the "likeness" of their behavior at single and double slits to that of a single filament lamp seen through such openings on a slit-plate. Through the well-known PSSG film loops, the reflection and refraction of ripple tank waves are demonstrated "modeled" analogously to what was seen with the laser beam at an air-water interface. This wave analogue model, articulated with apparatus, is then articulated further through line drawings, as by the usual procedures except explaining that they are analogue models. This evolution may be seen through a series of viewgraphs, Figures 4 to Figures 7b, (VG 5 through VG 8). Thus in the background of the abstract model is a series of successively refined analogue models, until only the well-known trapezoid is left (VG 8). Two overlays then show the preparation and algebraic deduction of Snell's Law from the wave model now interpreted as a paradigm. The advantages of this approach are many: First, the student sees the evolution from a demonstration of the phenomena, through the typology (sometimes aided with analogously modeled demonstrations) to the abstract model which can be proposed as a paradigm. Second, the proposed paradigm in physics can be tested by its power in deducing previously obtained empirical results. Third, students may better understand the utility of models in understanding and doing physics. A disadvantage is that students sometimes are confused by the first step; a scale

or dimension change is not as obvious to them as it is to instructors!

Finally, a commonly used typology for simple harmonic motion is shown by a viewgraph, (VG 9), with an overlay as another example.

FROM ICONS TO PARADIGMS IN LIGHT AND COLOR

by

John B. Newman

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Harry Bates
Thomas Krause

HAGGETT'S TYPOLOGY - ADAPTED:

ICONIC Model - all or almost all features of the original but with a scale and/or a dimensional change,

ANALOGUE Model - like one or more essential features of the original,

ABSTRACT, or SYMBOLIC, Model
- essential features with variables and concepts added, sufficient for experimentation,

PARADIGM, a Model
- casually related features and concepts,
- validated by experiments,
- open to continuing experimentation,
- useful for predicting outcomes,
- - a RESEARCH Model.

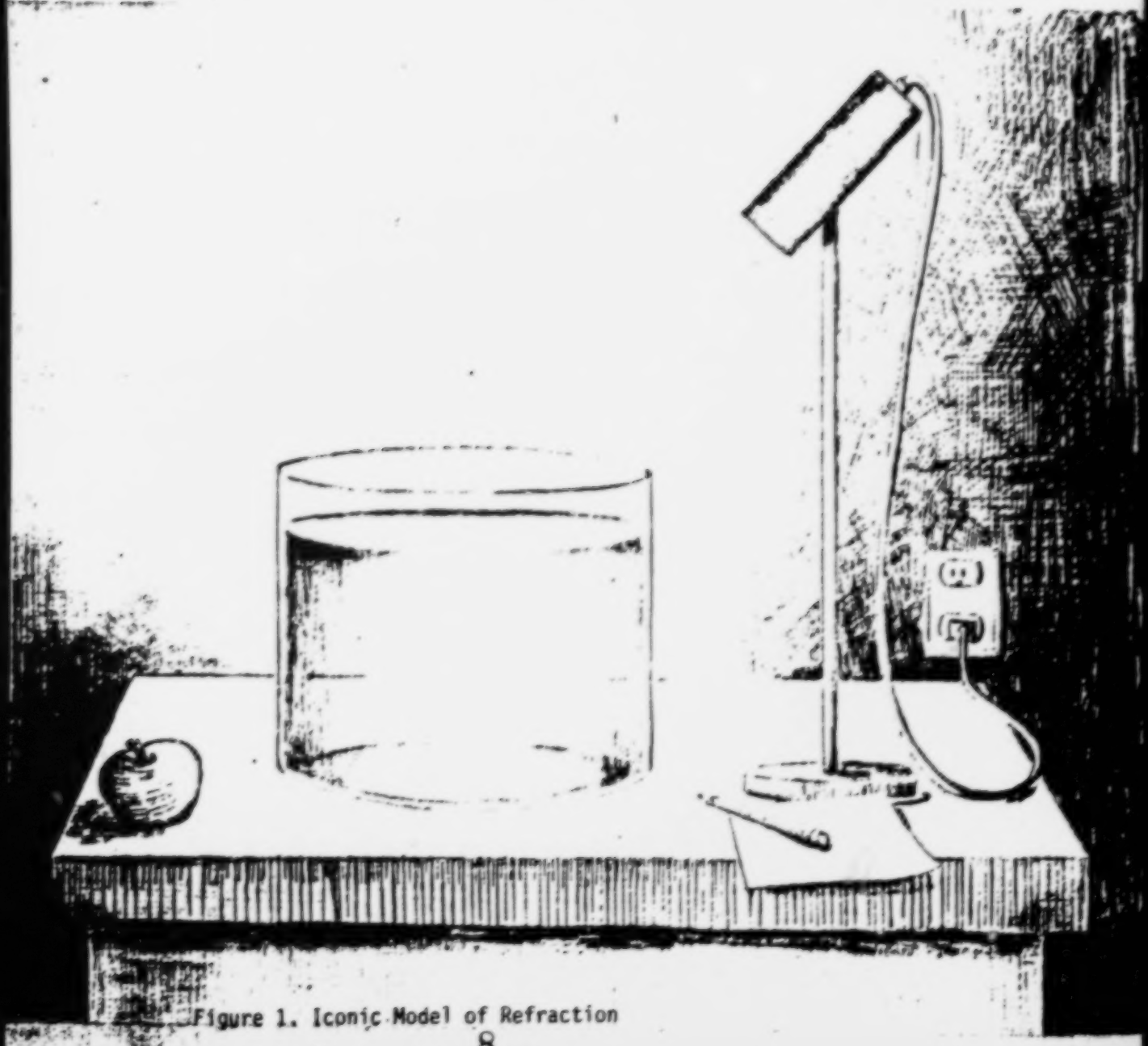
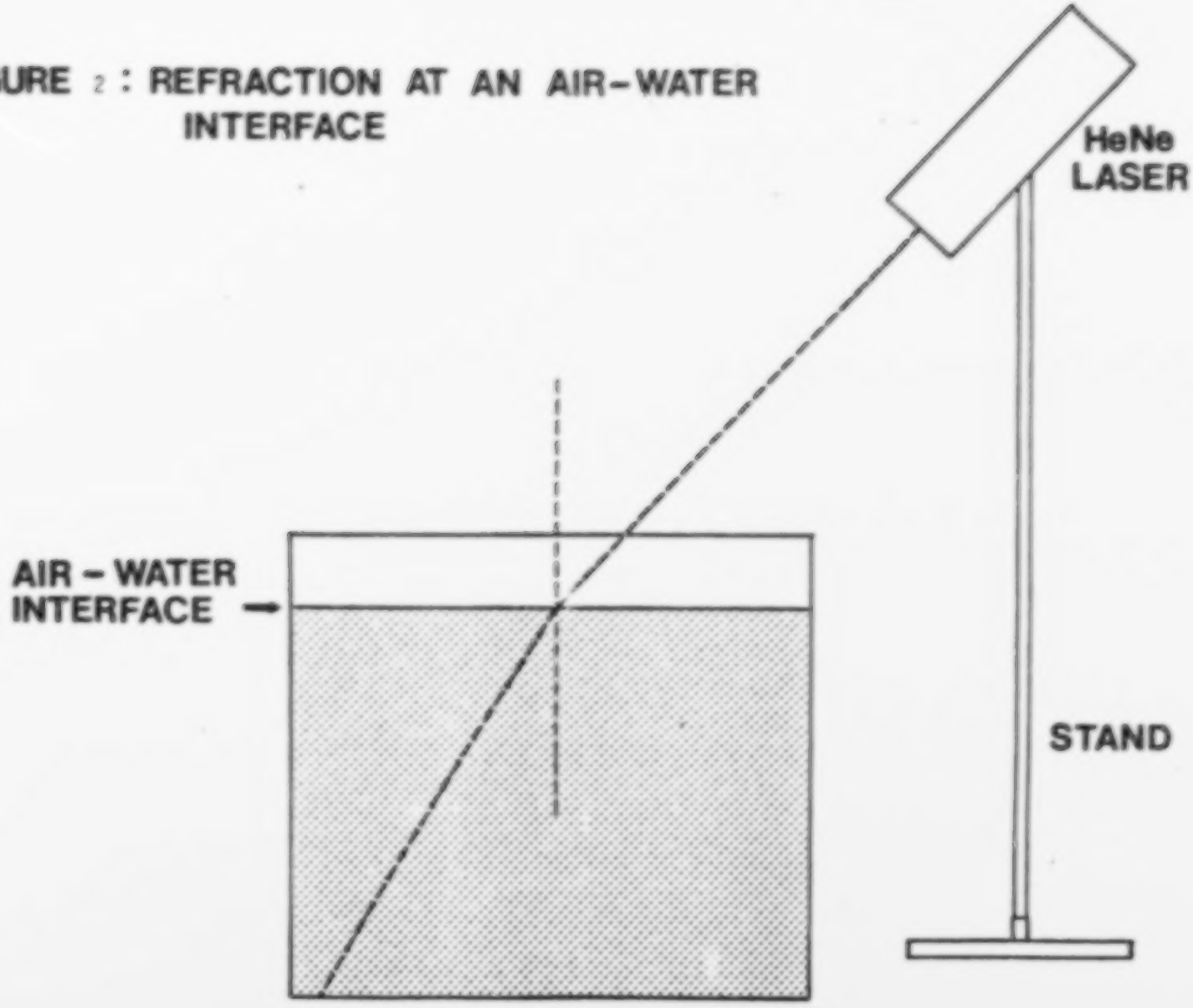


Figure 1. Iconic Model of Refraction

Overlay for Figure 1

FIGURE 2 : REFRACTION AT AN AIR-WATER INTERFACE



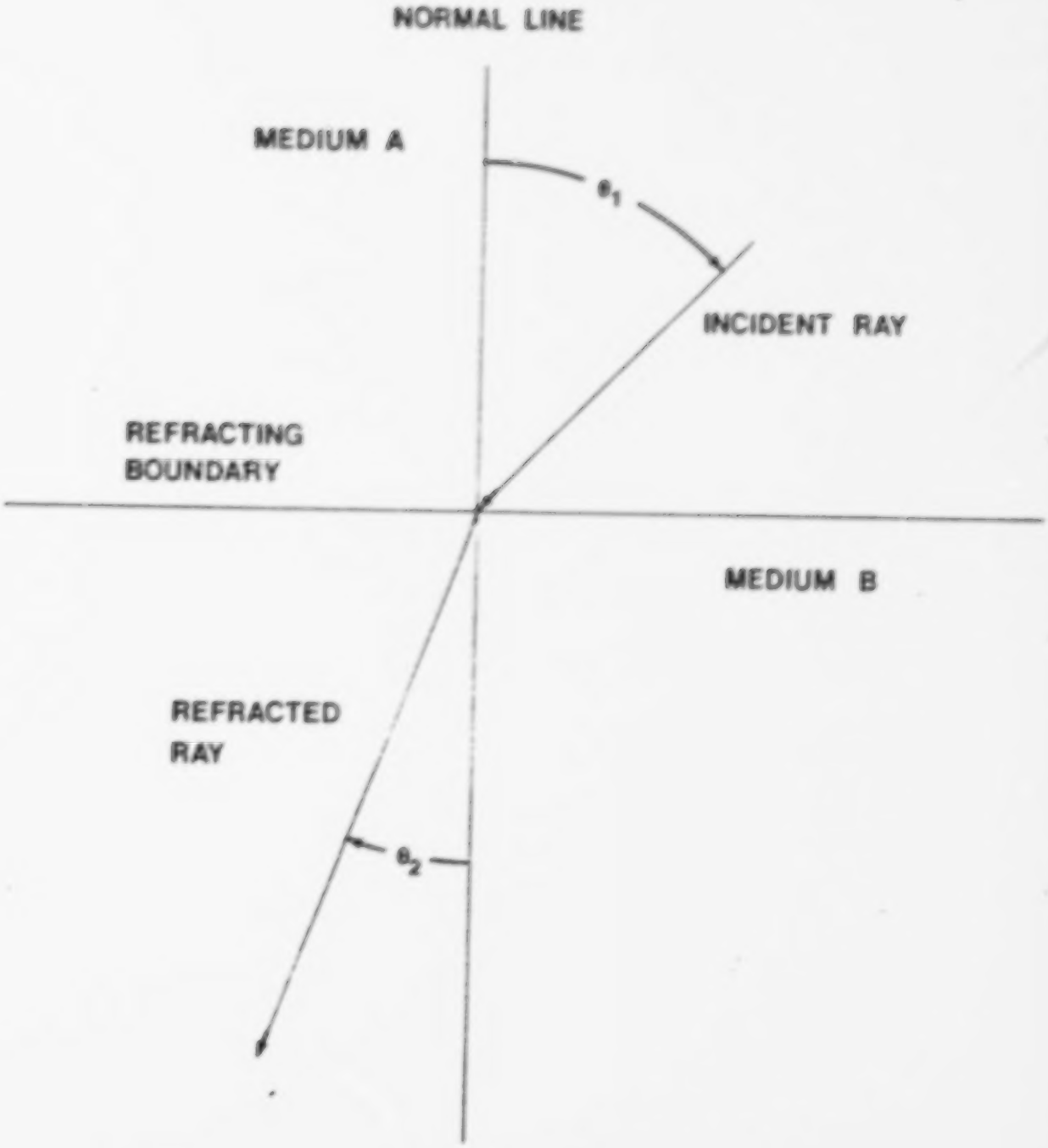


FIGURE 3. ANGLES USED IN SNELL'S LAW

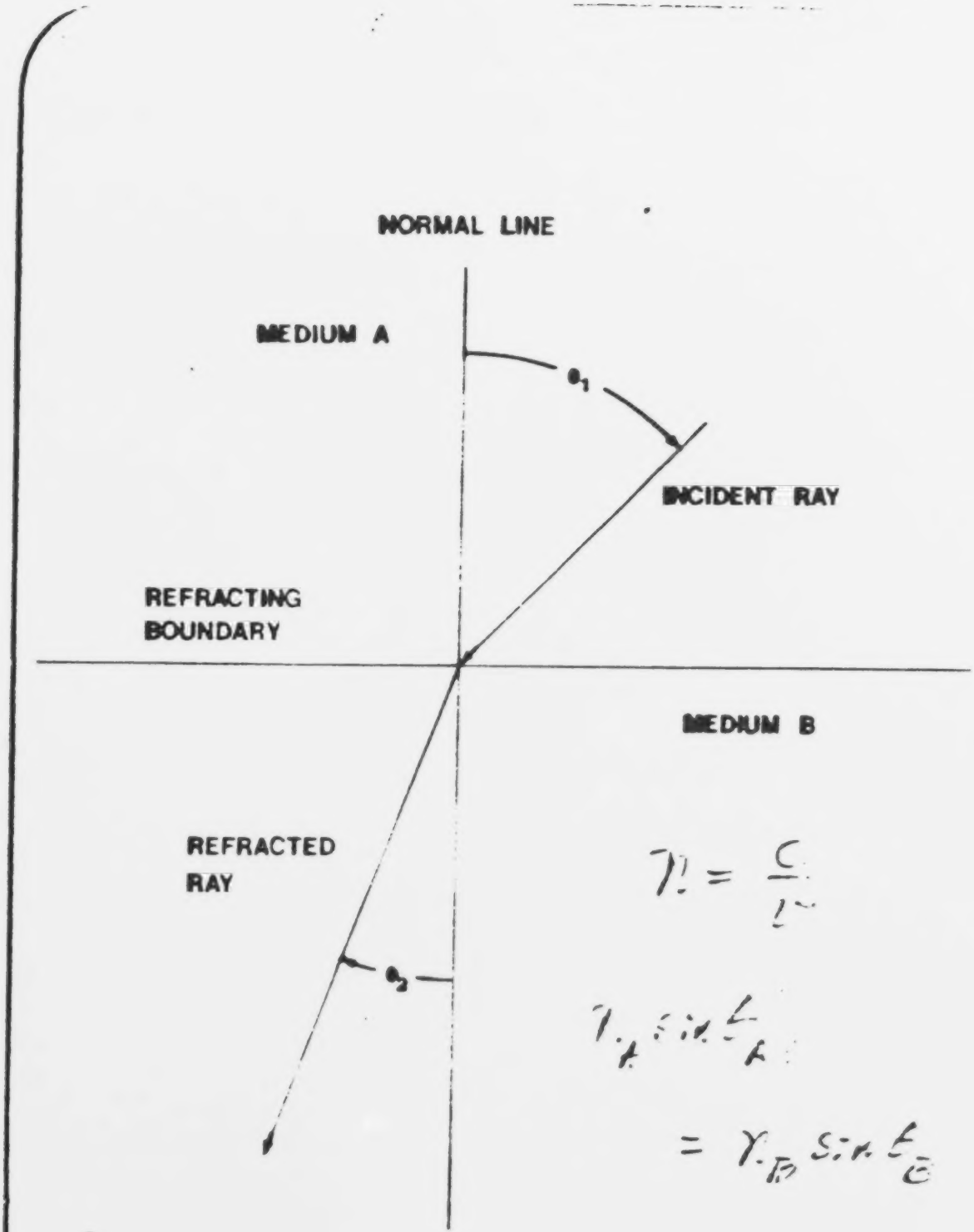
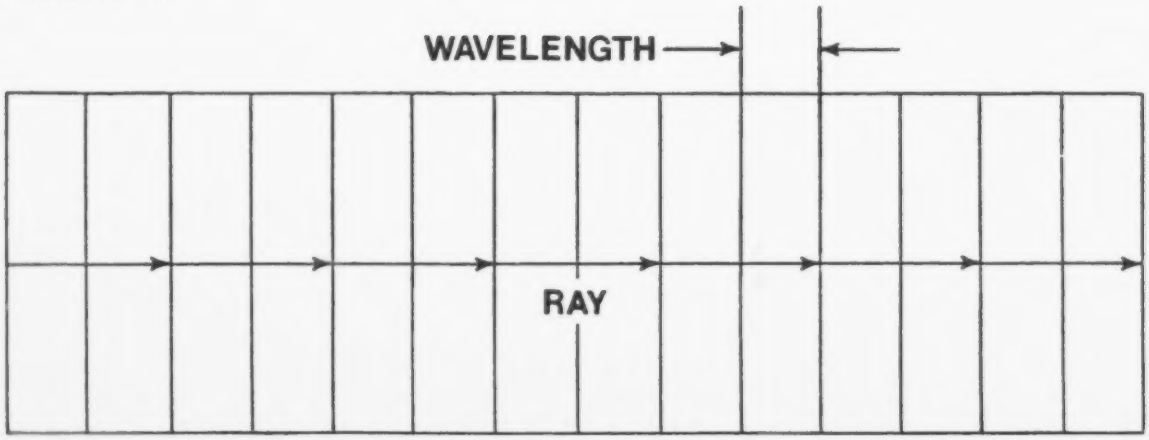
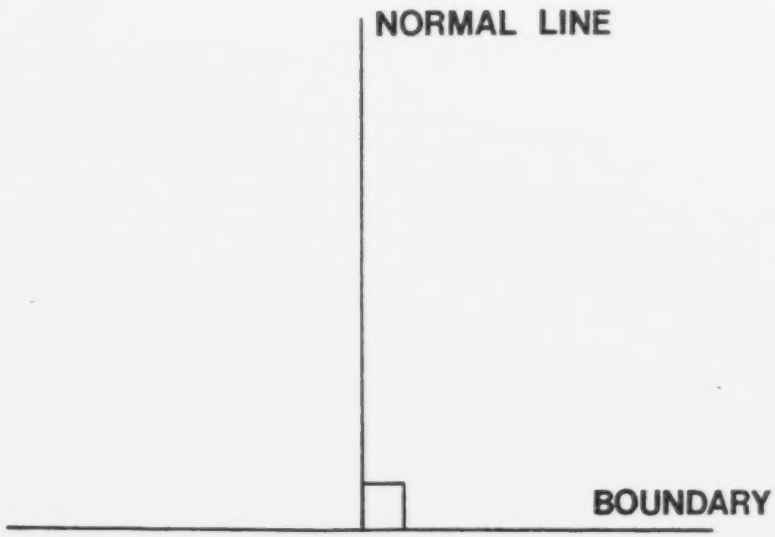


FIGURE 3. ANGLES USED IN SNELL'S LAW

FIGURE 4.



ANALOGUE MODEL OF PARALLEL LIGHT WAVES



BOUNDARY AND NORMAL CONSTRUCTION

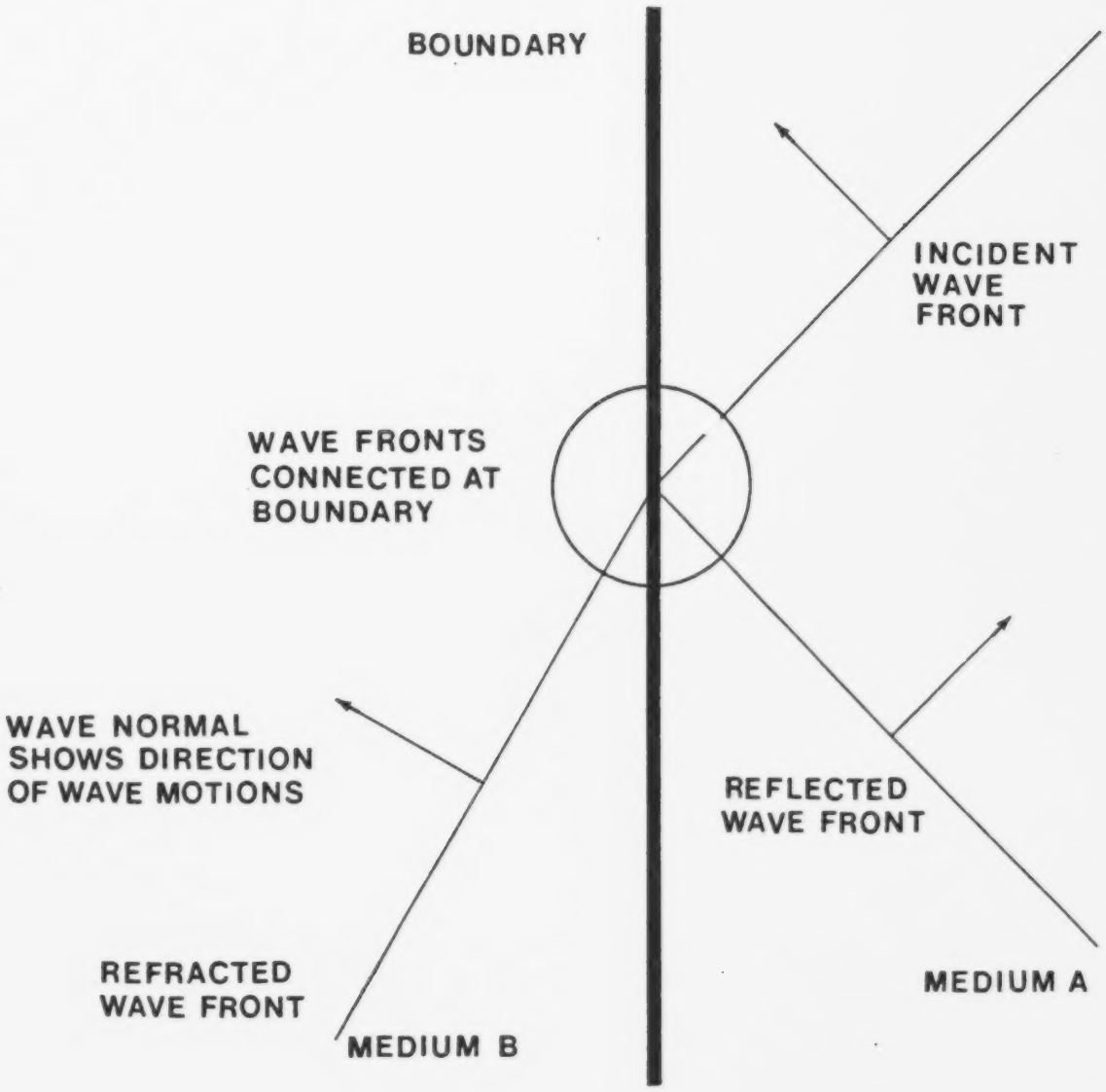


FIGURE 5. THE RELATIONSHIP BETWEEN WAVE FRONTS AT A BOUNDARY

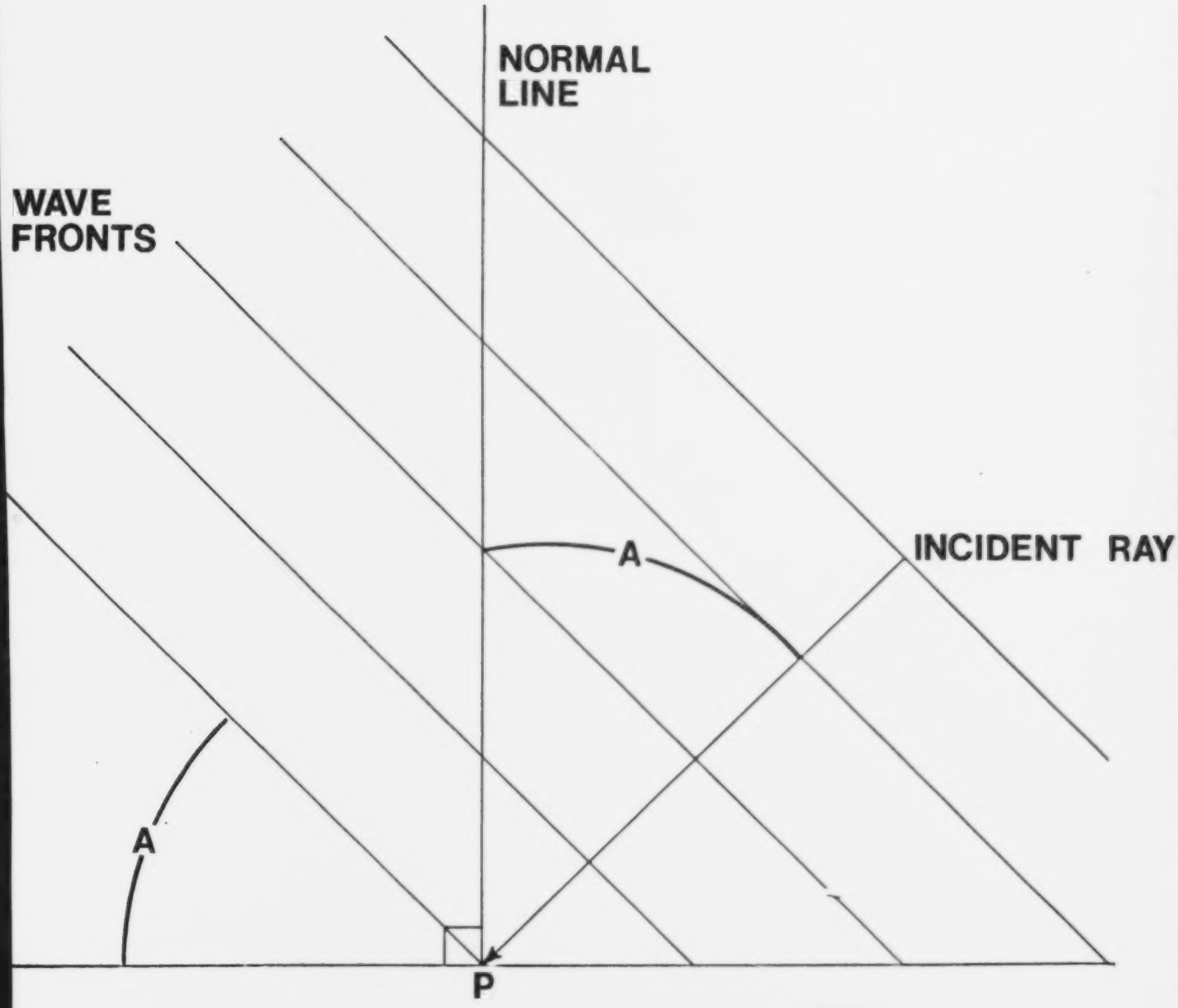


FIGURE 6. IMPORTANT ANGLES AT A BOUNDARY

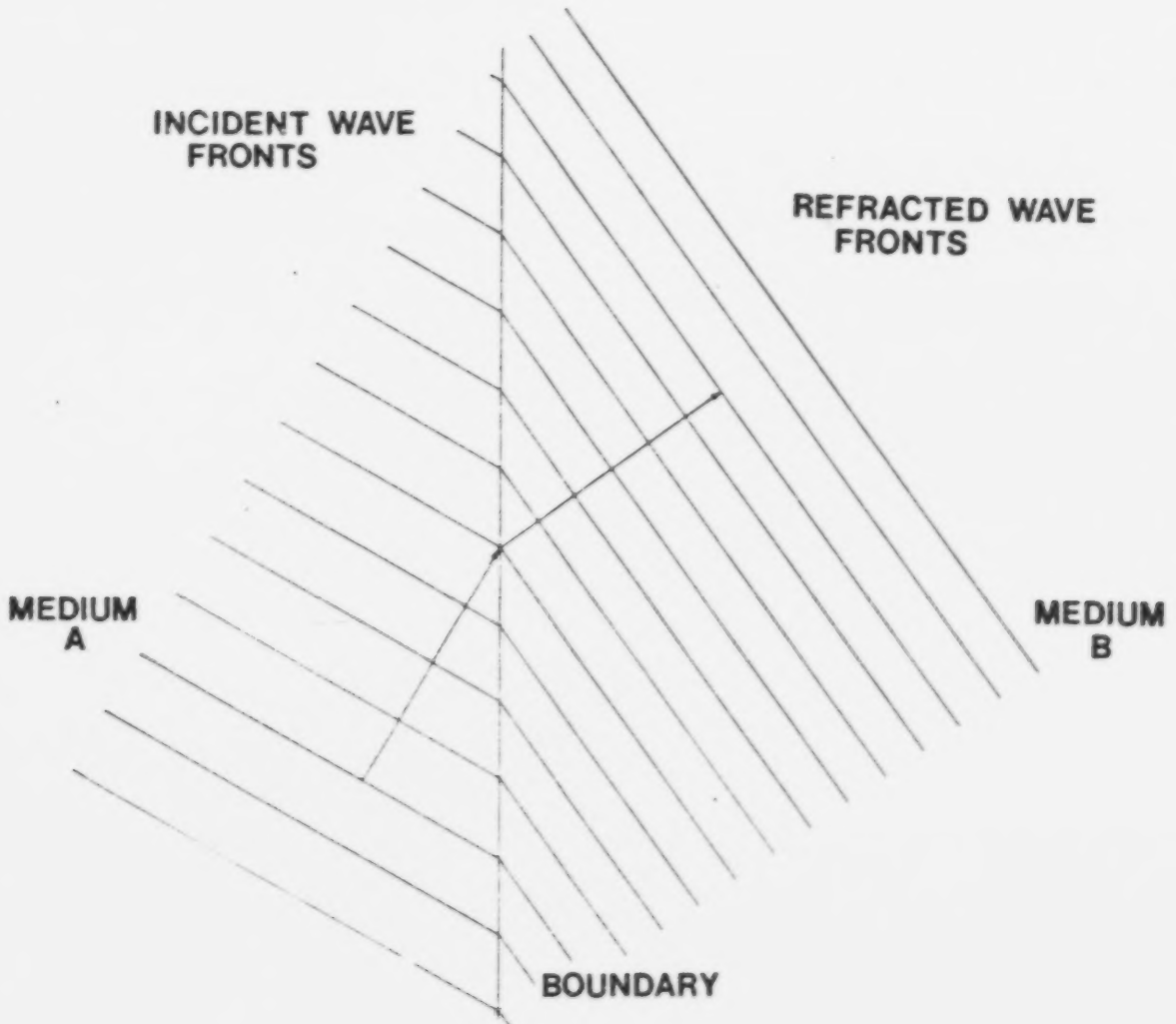


FIGURE 7a. THE MOTION OF WAVES ACROSS A BOUNDARY

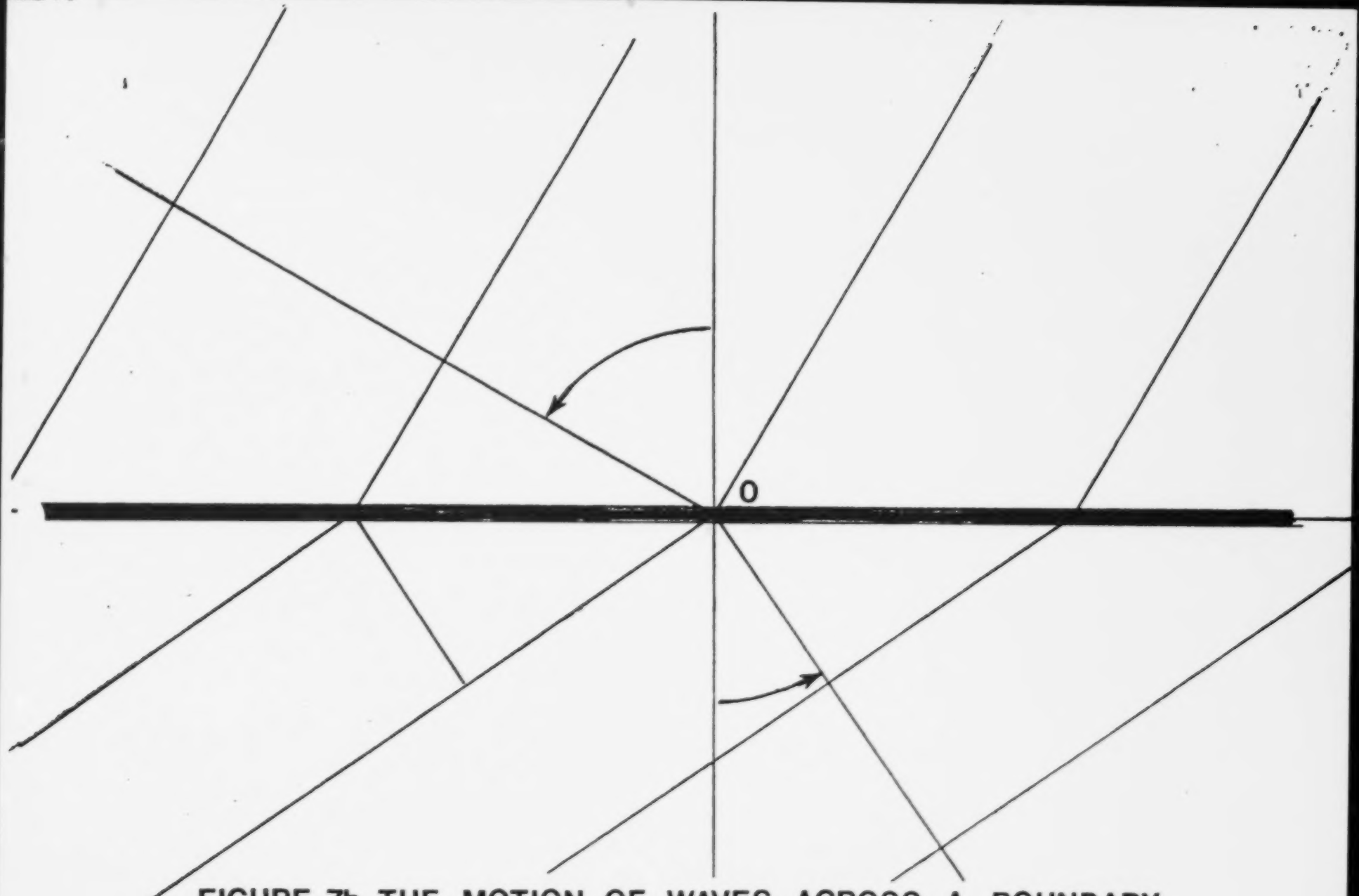


FIGURE 7b. THE MOTION OF WAVES ACROSS A BOUNDARY

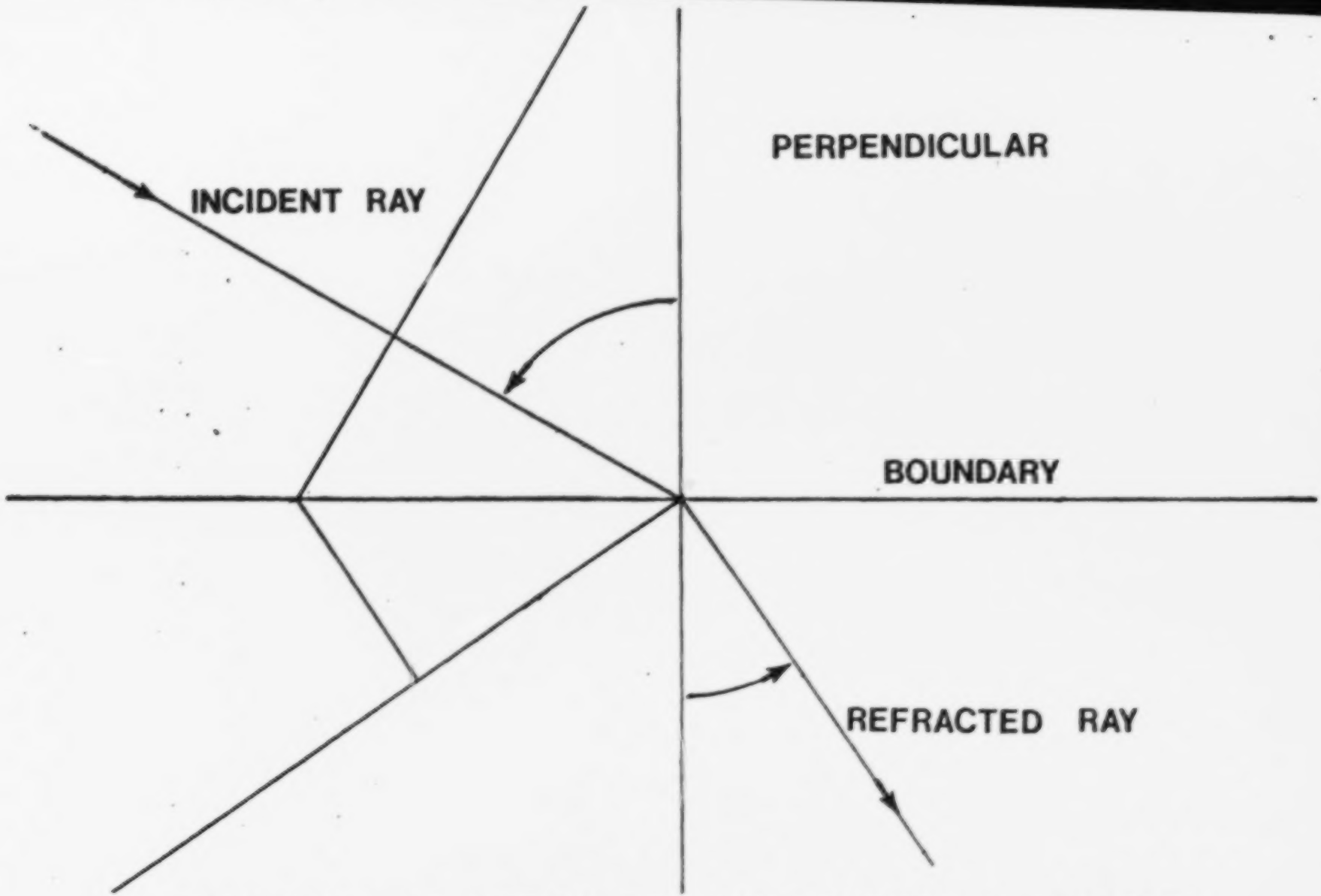
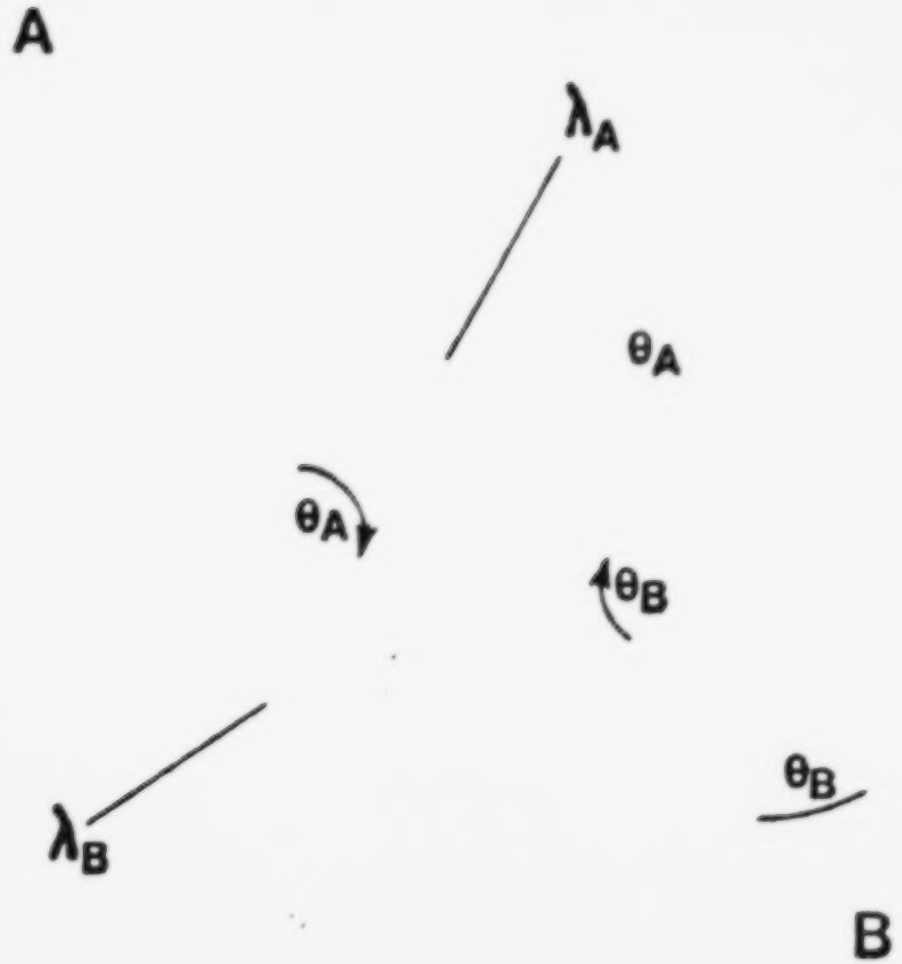


FIGURE 7c. THE MOTION OF WAVES ACROSS A BOUNDARY



First Overlay, Fig. 7

$$\sin\theta_A = \lambda_A / OP$$

$$= \lambda_o / n_A OP$$

$$n_A \sin\theta_A = \frac{\lambda_o}{OP}$$

P

$$v = f\lambda$$

$$n = c/v = \frac{f\lambda_o}{f\lambda}$$

$$n_m = \lambda_o / \lambda_m$$

$$\lambda_m = \lambda_o / n_m$$

$m = A$ or B

$$\sin\theta_B = \lambda_B / OP$$

$$= \frac{\lambda_o}{n_B OP}$$

$$n_B \sin\theta_B = \lambda_o / OP \longrightarrow n_A \sin\theta_A = n_B \sin\theta_B$$

Second Overlay Fig. 7C

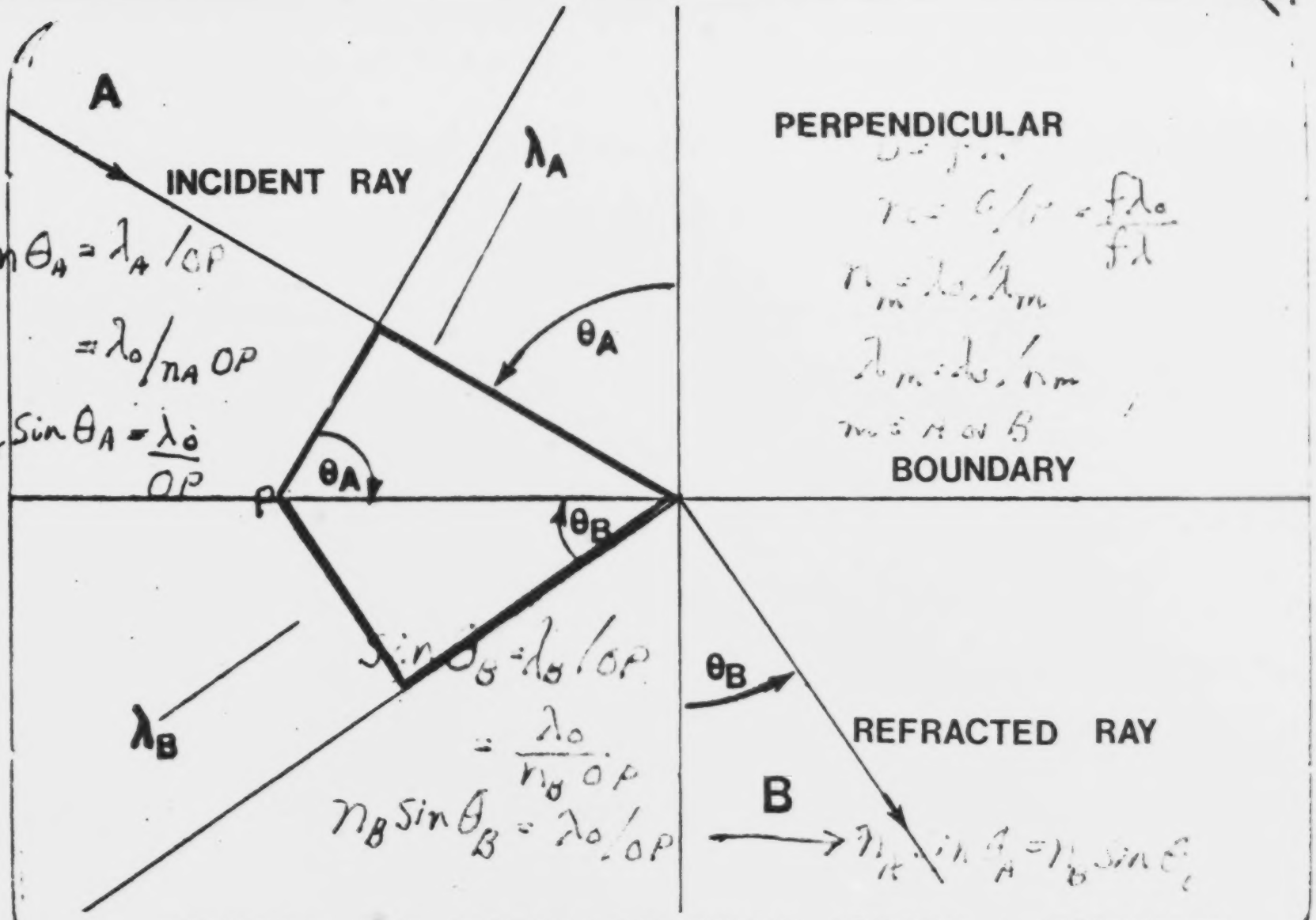


FIGURE 7c. THE MOTION OF WAVES ACROSS A BOUNDARY

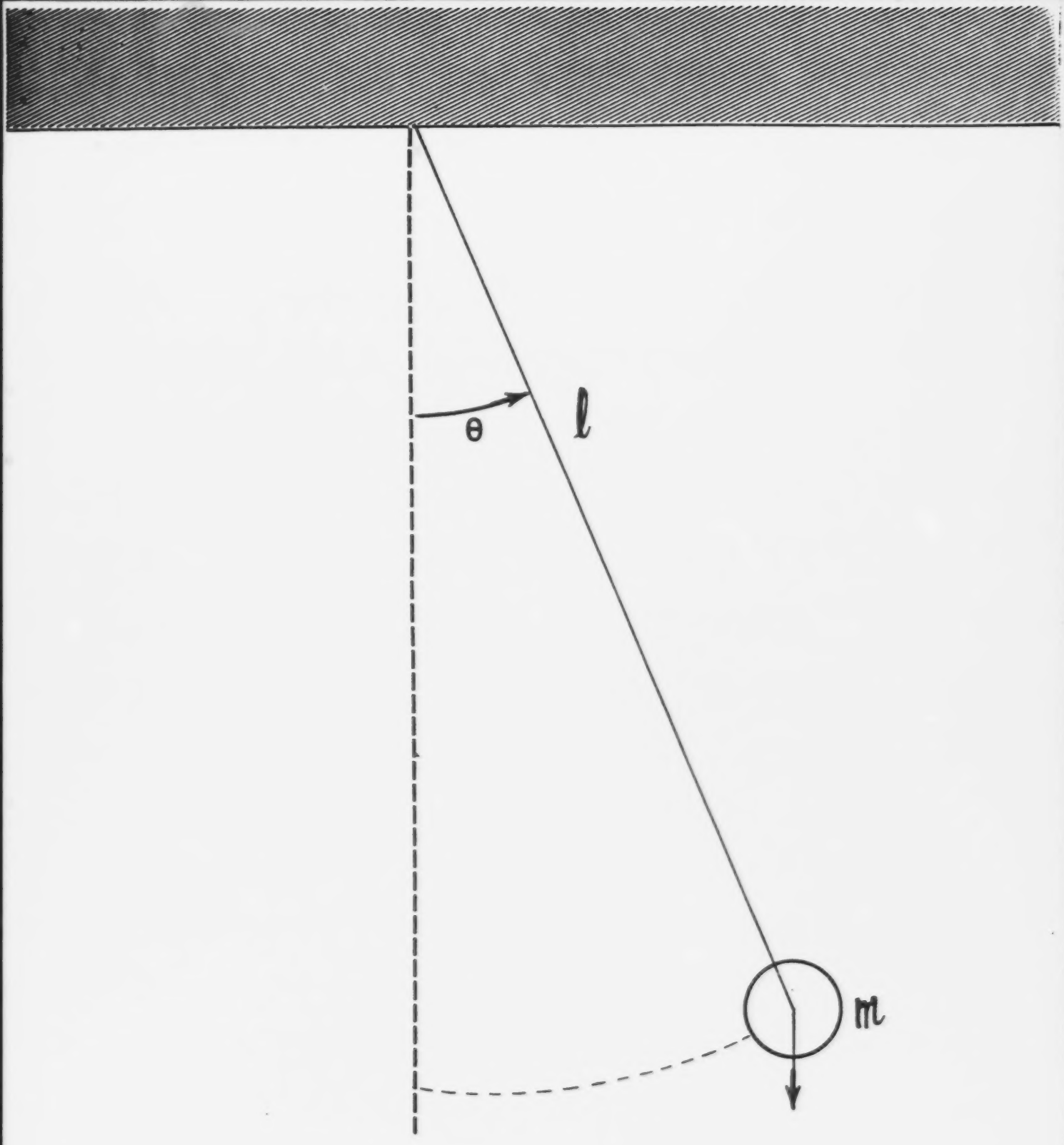


FIGURE 8. SIMPLE PENDULUM

$$I\alpha = -\tau$$

$$ml^2 \frac{d^2\theta}{dt^2} = mgl\sin\theta$$

for small θ, $\sin\theta \approx \theta$

$$ml^2\ddot{\theta} = -mgl\theta$$

$$\ddot{\theta} + g/l\,\theta = 0$$

$$\boxed{\ddot{x} + \omega_0^2 x = 0}$$

Overlay for Fig. 8

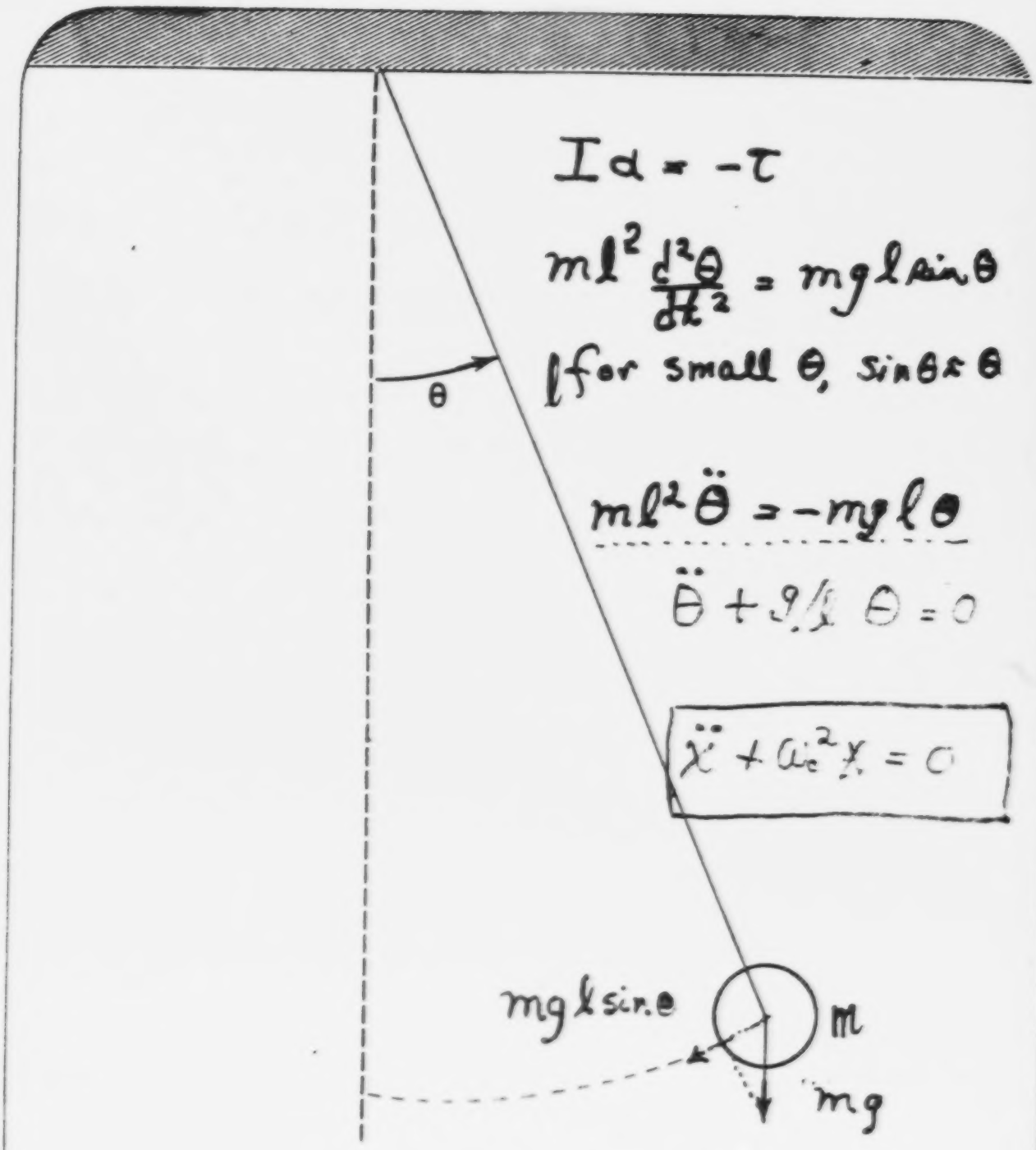


FIGURE 8. SIMPLE PENDULUM